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Magnetic properties of La-substituted $NiFe_2O_4$ via egg-white precursor route

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ABSTRACT

Nano-sized $NiFe_{2-x}La_xO_4$ ferrites (x=0.00, 0.01, 0.02, 0.03, 0.04, 0.5, 0.07 and 0.09) were synthesized for the first time by using metal nitrate and egg-white extract in aqueous medium. The ferrites were characterized by DTA-TG, XRD, TEM, FT-IR and VSM techniques. The thermal decomposition behavior revealed that the precursors were completely decomposed at about 420 °C. TEM image shows agglomerated nanoparticles with crystallite sizes agrees well with that estimated by XRD measurement. XRD patterns show a secondary phase of $LaFeO_3$ besides the cubic structure of the La-substituted ferrites. The lattice parameters, X-ray density and crystallite size were found to increase with the increasing La content. The VSM measurement exhibited a ferromagnetic property for all the samples at room temperature. With increasing La, M_s was found to decrease while H_c increased. The decrease in the saturation magnetization is attributed to the paramagnetic properties of lanthanum, which prefer to substitute iron present in the octahedral sites. The increase in the coercivity is due to either the stronger magnetocrystalline anisotropy induced by La substitution or the change in the crystallite size.

1. Introduction

Ferrites are magnetic oxide materials with semiconducting nature, which are of great technological importance since they combine high resistivity along with highly useful magnetic properties. They are applicable in many magnetic devices due to their low electrical conductivity as compared to that of other known magnetic materials. They have also potential applications in high-density magnetic recording, microwave devices and magnetic fluids [1].

Nickel ferrite ($NiFe_2O_4$) is one of the most important spinel ferrites as well as a typical spin soft-magnetic ferrite. It has cubic inverse spinel structure showing ferrimagnetism that originates from magnetic moment of anti-parallel spins between Fe^{3+} ions at tetrahedral sites and Ni^{2+} ions at octahedral sites [1].

Many efforts have been made to improve the basic properties of ferrites by substituting or adding various ions of different valence states depending on the applications of interest. Generally, the substitution of paramagnetic or diamagnetic ions in the pure ferrites results in the modification of their structural, electrical and magnetic properties [2,3].

Compared to the bulk form, nanoscaled ferrite spinel shows essentially different magnetic properties, which has attracted considerable attention. Recently, there are a lot of conventional techniques for preparation of nanoparticles [4–10]. In the present study, we report the synthesis of nanocrystalline $NiFe_2O_4$ at a relatively low temperature by an environmental friendly and coast effective method using egg-white precursor [11,12].

The aim of the present work is to investigate the effect of lanthanum substitution for iron on the structural and magnetic properties of nickel ferrite. So far as per the knowledge of the researcher no literatures are available on this aspect.

2. Experimental procedure

All chemicals used in this study were of analytical grade and were used without any further purification. Nickel nitrate [$Ni(NO_3)_2 \cdot 6H_2O$], iron nitrate [$Fe(NO_3)_3 \cdot 9H_2O$] and lanthanum nitrate [$La(NO_3)_3 \cdot 6H_2O$] were used as reactants. The preparation procedure is as mentioned elsewhere [12]. 60 ml of freshly extracted egg-white dissolved in 40 ml of distilled water through vigorous stirring was used as a binder cum gel, for each preparation. Stoichiometric amounts of metal nitrates to prepare $NiFe_{2-x}La_xO_4$ (where x=0.00, 0.01, 0.02, 0.03, 0.04, 0.05, 0.07 and 0.09) were dissolved together in a minimum amount of distilled water to get a clear solution. The egg-white solution was then added slowly, at room temperature with vigorous stirring, to the nitrates solution without any pH adjustments. After constant stirring for 30 min, the resultant sol–gel was evaporated at 80 °C until a dry precursor was obtained. The grounded precursors were then calcined in a muffle furnace, at 550 °C for 2 h, to obtain their corresponding ferrites.

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